Final Exam in the course "Hybrid Electric Drives" at LTH

Fall 2011

Questions to Francisco Marquez

Means of assistance: Calculator
Grades:
- 20-30 p: 3
- 31-40 p: 4
- 41-50 p: 5

1 Energy consumption

a. A liter of diesel or gasoline contains about 10 kWh of energy. How much of this energy reaches the wheels in a truck on the highway and in a car in city traffic, both conventional vehicles? (2p)

- about 40 % in the truck and 10 % in the car. I want the students to indicate that they understand that a truck on the highway operate near maximum efficiency but a car at low efficiency. The exact figures are less important.

b. Same as previous question, but now with hybrid vehicles? (3p)

- about 40 % in the truck and 30 % in the car. I want the students to indicate that they understand that the truck will not be significantly helped by hybridisation, but the car will. The exact figures are less important.

c. Assume that a car in slow city traffic need 2 kW of average tractive power, and that the load on the 12 V system is 2 kW. Which of these power consumptions has the biggest influence on the fuel consumption, and why? (2p)

- The 12 V system due to a low efficiency of the generator

d. What is roughly the efficiency of a DC/DC converter from 300 V to 12 V? (3p)

- over 90 %, probably over 95%.

2 Hybridisation, potential

a. Which vehicle has generally the highest hybridisation potential, a Nissan Micra with a 1.4 liter diesel engine or an Aston Martin with a 4.1 liter gasoline engine? Explain! (2p)

- The Aston Martin due to an oversized engine that is likely to run more often on low efficiency.

b. A hybrid City Bus can have either a parallel or series hybrid system. Make a rough design of the two traction systems assuming that the maximum wheel power is 200 kW in both alternatives. (2p)

- series: ice/gen/trac = 60/50/200 kW, roughly
- parallel: ice/trac = 150/50 kW, roughly

c. Which of these vehicles is likely to have the highest system cost (1p)

- the series due to more total installed power converters

d. Which of these buses is likely to have the lowest fuel consumption in a traffic flow with many stops and starts? (1p)
- The series due higher electric wheel power, useful in frequent regeneration

e. Which of these vehicles will have the lowest fuels consumption on the highway? (1p)
   - The parallel due fewer energy conversions

f. A Hauler/Loader = a construction equipment vehicle, has a relatively high hybridisation potential. Why? (3p)
   - A large quantity of energy is spent in hydraulics with relatively low conversion efficiency. The operation is usually very dynamic.
3 Hybridisation components

a. A combustion engine and an electrical machine are said to match well in terms of torque capabilities in a parallel hybrid electric drive train. Draw realistic maximum torque limitations in the diagram below and explain in your own words why these two machine types match so well. (3p)

b. A combustion engine vehicle providing 15 kW of wheel power needs to dissipate about 30 kW of heat. How high is the corresponding cooling power with an electric vehicle that provides 15 kW to the wheels? (2p)
- about 1.5 kW since the electric traction system efficiency most likely is above 90 %.

c. A Cessna Centurion (a small propeller driven aircraft) has a 224 kW combustion engine that runs at 135 kW average power in flight (306 km/h), a 250 litre gasoline tank and a take off weight of 1724 kg.

If it was to be made electric, how big batteries would it need to bring along the same energy as the combustion version and what would be the weight of the vehicle? (2p)
- 250 litre gasoline = 2500 kWh = 2500/0.1 kg = 25000 kg >> take of weight. The student could (better) account for the higher conversion efficiency of the electric aircraft and thus bring less batteries, but the result would still be devastating.

d. Two identical electric vehicles starts the same trip with full batteries. Vehicle A runs the battery down to 30 % SOC and then recharges. Vehicle B runs down to 80 % SOC and recharges. Which of the two vehicles will last the longest distance before the batteries end of life? Motivate! (3p)
- With 70 % DoD the lifetime may be 5000 cycles. With 20 % DoD the lifetime may be 100000 cycles. Thus the total converted energy will be 20*100000/(70*5000) = more than 5 times higher for the one that recharges more frequently.

4 Charging
We are used to “charging” (= filling the tank of) conventional cars in very short time, assume 3 minutes to provide 500 km of driving range.

a. Discuss the realism of reaching the same range on one full charge with an equivalent electric vehicle. (2p)

- 500 km = 25 kWh used energy = 50 kWh battery energy = > 500 kg of batteries = not realistic compared to vehicle weight.

b. Discuss the possible charging time needed for an equivalent electric vehicle, with the same range. (2p)

- 25 kWh/3 minutes = 25 kWh/0.05 h = 500 kW = not realistic – no manually connected supply would provide that power and the battery would not accept it. A more realistic charging time is being connected to a few 10’s of kW charging power and thus the charging will still take about one hour.

c. Plug In can be arranged either as conductively or inductively connected. Assume 100 % efficiency of a conductively connected charger but 95 % on an inductively connected charger. What would be the national value of the difference in charging losses between these two connection alternatives if all vehicles were electric? Sweden generate 150 TWh of electricity and fill our vehicles with 80 TWh of fuel. (2p)

- 80 TWh fuel would correspond to roughly 30 TWh of electricity. The increased losses with inductive charging would be about 1.5 TWh = 1500 million kWh or 1500 million SEK (= about 2000-3000 jobs).

d. In a “Slide In” world (with an Electric Road network) the charging power can be supplied while driving. What implications does that have on range? (1p)

- With a reasonably small battery, enough to reach an Electric Road, an “infinite” range is obtained.

e. The battery is usually regarded as the weak point in electric hybridization of vehicles. With your assumptions on power and energy densities and a battery cost of 5000 SEK/kWh, what would be a suitable size of a battery for a “plug in” hybrid that should be able to drive at least 50 km on pure electric drive in mixed city/highway traffic, using your own assumption on electric energy consumption in kWh/km? The answer should include your assumptions of DOD, cycle life estimation and combined energy and battery cost per 10 km. (3p)

- 50 km = 10 kWh DoD = 20 kWh battery (@50%DoD) = at least 100000 cycles lifetime. 100000*50 km = 5000000 km life -> 5000 SEK/kWh*20 kWh/500000 km = 0.2 SEK/km battery cost. Energy use is 0.2 kWh/km = also about 0.2 SEK/km.

5 **Auxiliaries and EMC**

a. Why cannot all electric loads on a vehicle, including the traction system if it is a hybrid vehicle, be run from the 12 V supply? (2p)

- to high currents at powers of 10’s of kW

b. Name at least three conventional auxiliary loads that could benefit from being converted from mechanical drive (belt) to electrical drive, and the type of benefit. (4p)

- water pump, air conditioning compressor, servo steering pump. All benefit on increased efficiency and simplified vehicle constructions.
c. What is an APU? Explain what it is used for and why. (3p)

- Auxilliary Power Unit, used to provide electric power from fuel at significantly higher efficiency than an (almost) idling combustion engine.